Research Square

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Network structure of daily life difficulties in children with attention- deficit/hyperactivity disorder: a cross-sectional network analysis

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Abstract

Background

Daily-life difficulties in children with attention-deficit/hyperactivity disorder (ADHD) severely compromises overall quality of life, social functioning, and academic engagement. These behaviors are influenced by environmental factors such as parenting stress and family adjustment. Grounded in network theory, this study aimed to examine the network structure of functional impairment in daily-life functioning in children diagnosed with ADHD, identify central and bridge nodes, and elucidate how parenting stress and family adjustment are embedded within this network, thereby providing novel targets for precision intervention.

Methods

We retrospectively included 1,188 children with ADHD aged 6–12 years from The Affiliated Suzhou Hospital of Nanjing Medical University. Impairment in daily-life functioning was assessed using the Questionnaire-Children with Difficulties (QCD), parenting stress using the Parenting Stress Index-4 Short Form (PSI-4 SF), and family adjustment using the Parenting and Family Adjustment Scales (PAFAS). Network structures were estimated using the EBICglasso method. Node strength, closeness, betweenness and bridge strength were computed to assess centrality and identify bridging nodes across domains. Stability and accuracy were assessed via bootstrap methods. Finally, an extended network incorporating family-system factors was constructed.

Results

Within the baseline QCD network, "Follows night instructions" (QCD16), "Trouble-free morning before school" (QCD4), and "Has same-age friends" (QCD9) exhibited the highest strength centrality. QCD4 and QCD16 also ranked high in closeness, whereas "Age-appropriate behavior at breakfast" (QCD3) demonstrated the highest betweenness. Bridge centrality analysis identified QCD4, "Likes going to school" (QCD5), and "Has accepting friends at school" (QCD7) as key bridge nodes connecting distinct temporal (time-of-day) dimensions. Case-dropping bootstrap analysis confirmed stability of strength centrality (CS-Coefficient = 0.789), closeness (0.667) and betweenness (0.545). In the extended network, the PSI Parent Domain (PSI-PD) was most strongly linked to the QCD Night dimension (w = − 0.763), the PSI Child Domain (PSI-CD) to QCD School (w = − 0.600) and After School (w = − 0.643), PAFAS Parental Teamwork (PAFAS-PN) to QCD Evening (w = − 0.427), and PAFAS Family Relationships (PAFAS-FR) to QCD Morning (w = − 0.250). PSI-CD (R^2 = 0.901) and PSI-PD (R^2 = 0.888) were the most predictable nodes, with most of their variance explained by connections within the network. The PSI Parent Domain (PSI-PD) showed the strongest negative association with the QCD Night dimension (w = − 0.763), reflecting that greater parenting stress corresponded to more severe nighttime difficulties.

Conclusions

Impairment in daily-life functioning in pediatric ADHD exhibit clear temporal clustering, with nighttime and morning routines forming core nodes while bridge nodes intensify stress across the day. These findings highlight that parenting stress and poor family adjustment have phase-dependent associations with children's difficulties, suggesting that clinical interventions should adopt family-system-oriented, temporally tailored strategies to maximize therapeutic efficacy.

Trial registration:

Not applicable.

Background

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders in childhood, characterized by inattention, hyperactivity, and impulsivity, with a global prevalence of approximately 5%–7% among children [1]. In the United States, a 2022 national survey reported that roughly one in nine children aged 3–17 years had ever received an ADHD diagnosis (11.4%), nearly one-third of whom had not received any targeted treatment [2]. Similarly, the first nationwide epidemiological survey in China showed a weighted prevalence of 17.5% for any mental disorder among children and adolescents aged 6–16 years, with ADHD ranking among the most prevalent conditions [3]. Children with ADHD exhibit significant functional difficulties across multiple temporal dimensions of the day [4, 5]. These pervasive daily impairments not only directly diminish quality of life for the child and family but may also exacerbate core symptoms through a reciprocal feedback loop of symptom presentation, functional impairment, and family stress [6, 7]. Therefore, a deeper understanding of the network structure of daily activities and adaptive behaviors in children with ADHD, alongside their relationship with family environmental factors, is essential for optimizing clinical assessment and designing targeted behavioral intervention strategies.

Traditionally, psychopathology has relied on latent-variable models that conceptualize mental disorders as sets of symptoms driven by a common underlying trait [8, 9]. Within this framework, symptoms are treated as interchangeable indicators, making it difficult to explain specific associations among symptoms, the role of key symptoms, or to provide empirical evidence for prioritizing interventions. The network approach to psychopathology has emerged as a novel paradigm that conceptualizes mental disorders as dynamic networks of interacting elements. Within this framework, nodes represent specific symptoms or functional impairments, while edges reflect partial correlations that control for all other variables in the system, thereby capturing direct conditional dependencies [10, 11, 12, 13]. Highly central nodes occupy core positions in the network structure, whereas nodes with high bridge centrality connect distinct functional dimensions or diagnostic categories [14]. Identifying these key nodes provides

valuable targets for precision interventions; disrupting these features can trigger cascade effects that systematically deactivate the broader network [15, 16].

In the ADHD field, network analysis has been widely used to explore core symptom architecture and their cross-symptom associations. Early research [17] found that "Loses things" and "Does not follow instructions" showed high betweenness centrality, serving as key bridges within the hyperactive/impulsive symptom cluster. In a large-sample study of 4,033 Chinese children with ADHD, Liu et al. [18] confirmed that "Easily distracted" and "Fidgets" were central bridge symptoms connecting the inattention and hyperactivity-impulsivity domains, demonstrating robust network invariance across sex, age, and presentation types. Recent studies have expanded network boundaries: Gauld et al. [19] identified emotional dysregulation as significant bridge linking the two ADHD dimensions in adults; Similarly, Tharaud et al. [20], utilizing the Adolescent Brain Cognitive Development (ABCD) cohort, demonstrated that "Catastrophizing" and "Distracted" functioned as key bridge nodes connecting childhood ADHD to adolescent depression. In addition, network modeling in young adults with ADHD [21] has identified neuroticism and oppositional defiant behaviors as cross-domain bridge features. These findings consistently indicate that nodes within the ADHD network are not uniform, with specific features playing distinct roles in maintaining network topology and driving comorbidity.

However, existing network analyses have focused predominantly on core symptoms (e.g., inattention, hyperactivity, impulsivity), paying less attention to functional impairments in daily life. Crucially, the daily functional impairments of children with ADHD impose a heavy burden on caregiving and family relationships [22]. The Questionnaire: Children with Difficulties (QCD) is a specialized instrument designed to assess these impairments, capturing parental reports of child adaptation across five temporal dimensions: morning, school, after school, evening, and night. While the QCD has been used to evaluate functioning in ADHD, autism spectrum disorder, and depressive disorders [23], previous studies (e.g., Usami et al. [4]) demonstrated that children with ADHD exhibit significantly lower functioning across all QCD domains compared to typically developing peers, with evening difficulties being the most prominent. Moreover, difficulty severity was positively correlated with symptom severity. However, to date, no study has employed network analysis to map the interaction patterns among QCD items or to identify bridging nodes across temporal domains. From a network perspective, functional difficulties across different time periods are not isolated; instead, they are mutually reinforcing and maintained through shared executive dysfunction, emotional dysregulation, and maladaptive family interaction patterns. Characterizing the clustering, central nodes, and bridge pathways of this system can elucidate the daily functional phenotypes of ADHD and provide empirical support for circadian-rhythm-aligned, time-of-day tailored behavioral interventions.

Meanwhile, behavioral problems in children with ADHD are closely intertwined with family environmental factors. The Parenting Stress Index (PSI) and the Parenting and Family Adjustment Scales (PAFAS) assess parental psychological stress and family functional adaptation, respectively. Extensive research demonstrates that parents of children with ADHD experience significantly elevated parenting stress, which is intricately linked to the child's core symptoms, functional impairments, and overall family

interaction quality [24, 25]. In addition, maladaptive family adjustment (e.g., emotional dysregulation, interpersonal conflict, and poor parental teamwork) is tightly linked to ADHD symptom severity and poor treatment response [26, 27]. Nevertheless, previous studies have primarily adopted variable-centered approaches, such as linear regressions or structural equation modeling, which treat parenting stress, family adjustment, and child difficulties as mutually independent latent constructs. While these methodologies elucidate macro-level associations, they obscure the micro-level conditional dependencies between specific family factors and discrete temporal functional impairments. Consequently, traditional frameworks cannot identify the precise topology or bridging pathways through which specific family-system nodes operate within the child's broader functional network.

Network analysis offers a way to overcome these limitations. By constructing an extended network that incorporates both symptom dimensions and environmental factors, researchers can simultaneously estimate partial correlations among symptoms, and between symptoms and environmental factors, within the same network model. This approach reveals how environmental factors are embedded in the symptom network, which symptom nodes they are most strongly connected to, and whether they serve as bridge nodes between symptom clusters [28, 29]. In the ADHD field, incorporating parenting stress and family adjustment into the child's difficulty network not only helps identify difficulty nodes most closely linked to family factors, but also reveals whether family factors play bridging or mediating roles between different symptom dimensions. This provides novel empirical evidence for developing precision intervention strategies from a family-system perspective. To date, however, no study has systematically examined the complex associations among parenting stress, family adjustment, and the daily functional network of children with ADHD from a network perspective.

In summary, this study aimed to systematically investigate the internal network structure of impairment in daily-life functioning among children with ADHD, and their relationship with family environmental factors using a network-analysis paradigm. The specific objectives were: (1) to construct an EBICglasso network based on 18 QCD items to reveal the clustering characteristics of impairment in daily-life functioning across temporal domains, identify central nodes (high centrality) and bridge nodes (high bridge strength) that connect different temporal dimensions, and evaluate network stability; and (2) to construct an extended network comprising the five QCD temporal dimensions, three PSI domains, and three PAFAS dimensions, to explore the network topology linking parenting stress, family adjustment, and the child's impairment in daily-life functioning network, identifying core and bridging features within this extended system. Ultimately, this study is expected to provide new theoretical perspectives and empirical support for precision assessments and family-system-oriented, comprehensive interventions for children with ADHD.

Methods

Study design and participants

This study employed a retrospective cross-sectional design. We included children with ADHD who attended the child health care outpatient clinics across four campuses (Main Campus, Women and Children Campus, Rehabilitation Campus, and Taihu Campus) of The Affiliated Suzhou Hospital of Nanjing Medical University between January 2021 and December 2024. Inclusion criteria were: (1) an independent diagnosis of ADHD established by at least two senior physicians according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) criteria; (2) age 6–12 years; (3) parents or primary caregivers capable of independently reading and completing the questionnaires; (4) eligibility of both treatment-naïve (first-visit) and previously diagnosed (re-visit) patients. Exclusion criteria were: (1) comorbid autism spectrum disorder, schizophrenia, intellectual disability, or other severe neurodevelopmental disorders; (2) participation in other clinical trials or psychological intervention studies within the preceding 3 months; (3) incomplete questionnaire profiles or evidence of insufficient effort responding (e.g., selecting the same response option for more than 10 consecutive items).

This study was approved by the Ethics Committee of The Affiliated Suzhou Hospital of Nanjing Medical University (approval number: 17-K-2025-170-K01) and was conducted in accordance with the Declaration of Helsinki. All parents or legal guardians of the participating children provided written informed consent. A total of 1,245 cases were initially screened; after excluding participants with missing data exceeding 20% or demonstrating invalid response patterns, a final sample of 1,188 valid participants was retained.

For the small proportion of missing item-level data (< 5%), multiple imputation by chained equations (MICE) was conducted using the *mice* package in R with predictive mean matching (PMM). Five complete datasets were generated, and network estimation was performed separately for each dataset. Edge weights and centrality indices were subsequently pooled using Rubin's rules to reduce bias associated with single imputation and maximize use of available data.

Measures

Questionnaire: Children with Difficulties (QCD)

The QCD was developed by Usami et al. [23] to assess daily-life functional difficulties in children and adolescents aged 6–18 years with ADHD during the most recent week. The scale comprises 20 items scored on a 4-point scale: 0 (very difficult), 1 (difficult), 2 (easy), and 3 (very easy), yielding a total score range of 0–60. The 20 items theoretically form six dimensions: morning/before school (items 1–4), school (items 5–7), after school (items 8–10), evening (items 11–14), night (items 15–18), and general behavior (items 19–20). Because the general behavior dimension (items 19–20) reflects overall functioning rather than time-of-day-specific difficulties, it was not included in the symptom network analysis; only the 18 time-of-day-specific items were retained as network nodes. The QCD has been standardized in Japanese child samples and demonstrated good internal consistency (Cronbach's α = 0.88) in a Chinese ADHD sample [30]. Higher QCD scores indicate better daily-life functioning, whereas lower scores indicate greater functional difficulty.

Parenting Stress Index-4 Short Form (PSI-4 SF)

The PSI-4 SF, developed by Abidin [31], is a widely used measure based on a comprehensive theoretical model of parenting stress and is designed to assess stress experienced by parents in their parenting role over the preceding 6 months. The scale comprises 36 items rated on a 5-point Likert scale (1 = "strongly disagree" to 5 = "strongly agree"), and includes three core subscales of 12 items each: the Parent Domain (PD), Child Domain (CD), and Life Stress Domain (LSD), as well as a defensive responding validity scale. Higher total and subscale scores indicate greater parenting stress. Abidin reported excellent internal consistency (Cronbach's α = 0.80–0.91) and test–retest reliability (r = 0.68–0.85), and strong correlations with the full-length PSI (r > 0.90), supporting good convergent and discriminant validity across clinical and community samples. In the present study, the three PSI-4 SF domain scores were included as node variables in the extended network to assess parental distress (PD), parent-perceived child behavior-related stress (CD), and life-event-related stress (LSD).

Parenting and Family Adjustment Scales (PAFAS)

The PAFAS was developed by Sanders et al. [26] as a comprehensive parent-rated measure of family functioning comprising a Parenting Scale and a Family Adjustment Scale, with a total of 26 items. The present study used the 11-item Family Adjustment Scale, which includes three dimensions: Parental Adjustment (4 items), Family Relationships (4 items), and Parental Teamwork (3 items). Items are rated on a 4-point scale ranging from 0 ("not at all") to 3 ("very much"), with lower scores indicating better family adjustment. The PAFAS has demonstrated acceptable internal consistency (Cronbach's α = 0.70–0.85) and structural validity across Australian and international samples. In the present study, scores for the three Family Adjustment Scale dimensions (PAFAS-PA: Parental Adjustment; PAFAS-FR: Family Relationships; PAFAS-PT: Parental Teamwork) were used as extended-network nodes.

Common method bias examination

Because all data in this study were derived from parent self-report questionnaires, common method bias (CMB) may be present. We employed Harman's single-factor test to conduct a preliminary assessment of CMB [32]. Specifically, all items from the QCD, PSI-SF, and PAFAS were entered into an exploratory factor analysis using principal component analysis (PCA), and the variance explained by the unrotated first factor was examined. A variance contribution below the conventional threshold of 40% was interpreted as indicating that CMB was not substantial [33].

Network analysis

Network estimation

We used Gaussian graphical models (GGMs) to estimate conditional dependencies among variables. In a GGM, nodes represent variables, and edges represent partial correlations between pairs of variables after conditioning on all other variables in the network. To reduce overfitting and improve interpretability, we applied graphical least absolute shrinkage and selection operator (GLASSO) regularization combined with the extended Bayesian information criterion (EBIC), implemented using the EBICglasso method [10, 13, 34].

Specifically, network estimation was conducted using the *qgraph* package based on a polychoric correlation matrix, given that QCD items are ordinal categorical variables. The tuning parameter γ was set to 0.50 to balance model fit and sparsity. A regularization path over 100 values of λ was evaluated, and the optimal model was selected by minimizing the EBIC. To further aid interpretability, a threshold of $r > 0.10$ was applied for visualization, such that only edges exceeding this absolute correlation magnitude were displayed. Network visualization employed a Fruchterman–Reingold force-directed (spring) layout. Blue edges indicate positive partial correlations and red edges indicate negative partial correlations, with edge thickness and transparency proportional to the magnitude of the edge weights. Nodes were color-coded according to time-of-day domain (morning, school, after school, evening, night).

Network centrality indices

To identify the most influential nodes in the network, standardized centrality indices (z-scores) were computed:

(1) Strength centrality, defined as the sum of absolute edge weights connected to a given node, reflecting its overall connectivity and direct influence within the network [35]. In psychopathological networks, strength centrality is considered the most stable and reliable centrality metric [36].

(2) Closeness centrality, defined as the inverse of the sum of the shortest-path distances from a given node to all other nodes, reflecting its proximity to the rest of the network and its efficiency in information transmission.

(3) Betweenness centrality, defined as the number of times a node lies on the shortest path between any two other nodes, reflecting its potential role in controlling information flow as a "bridge."

(4) Expected influence (EI), proposed by Robinaugh et al. [15], defined as the signed sum of edge weights connected to a node (without taking absolute values). This metric accounts for both activating (positive) and inhibitory (negative) connections and therefore provides a more accurate estimate of a node's net influence on overall network activation or suppression.

All centrality indices were computed using the *qgraph* and *networktools* packages and standardized to z-scores to facilitate comparability across metrics.

Bridge symptom analysis

To identify key bridge nodes connecting different time-of-day difficulty dimensions, we adopted the bridge centrality framework proposed by Jones et al. [14].

Bridge strength is defined as the sum of the absolute edge weights connecting a given node to nodes in other communities (i.e., other time-of-day dimensions), reflecting its overall cross-community connection connectivity. Bridge expected influence retains the sign of edge weights and reflects the node's net activating or inhibitory influence on nodes in other communities. Higher bridge centrality values indicate that a symptom plays a more important role in linking difficulties across different time periods and may promote cross-dimensional symptom activation, making it a potential target for interventions aimed at disrupting symptom propagation across daily contexts.

Node predictability

To evaluate the extent to which the network model explained variance for each node, we used the *mgm* package to compute node predictability, expressed as R^2 [37, 38]. Predictability reflects the degree to which a node's variance can be explained by its directly connected neighboring nodes; higher R^2 indicates that the node is more driven by intra-network factors, whereas lower R^2 suggests greater influence from extra-network factors (e.g., genetic, biological factors, or measurement error). This index helps distinguish core nodes driven by the network from nodes more strongly influenced by external factors, providing important information for understanding symptom maintenance mechanisms [38].

Network stability and accuracy assessment

Network stability and accuracy were evaluated using the *bootnet* package [10]. The following procedures were performed:

(1) Non-parametric bootstrap: the original sample was resampled with replacement 500 times; the network was re-estimated for each bootstrap sample, and edge weights were computed to obtain 95% confidence intervals (CIs) for each edge weight. An edge was considered statistically significant if its 95% CI did not include zero.

(2) Case-dropping bootstrap: by progressively dropping random proportions of cases and re-estimating the network and centrality indices, the stability of centrality indices was assessed. The correlation stability coefficient (CS-Coefficient) was used as a quantitative metric, defined as the maximum proportion of cases that could be dropped while maintaining a high correlation ($r = 0.70$) between centrality-index rankings and those from the full sample. Following Epskamp et al.'s recommendations, a CS-Coefficient ≥ 0.25 is considered the minimum acceptable threshold, and ≥ 0.50 indicates good stability [10].

(3) Bootstrap difference tests: based on bootstrap samples, pairwise difference tests ($\alpha = 0.05$) were performed for edge weights and centrality indices to assess whether differences in centrality rankings or edge-weight magnitudes between nodes were statistically significant [10].

Extended network analysis

To examine the association patterns between impairment in daily-life functioning in children with ADHD, parenting stress, and family adjustment, we further constructed an extended network. First, the 18 QCD items were aggregated into five dimension mean scores (morning/before school, school, after school, evening, night). These were combined with the three PSI-SF dimensions (Parent Domain [PD], Child Domain [CD], Life Stress Domain [LSD]) and the three PAFAS dimensions (Parental Adjustment [PC], Family Relationships [FR], Parental Teamwork [PN]) to form an 11-node set. The extended network was then estimated using the same EBICglasso method (γ = 0.50), followed by thresholding (|r| > 0.10) and visualization. In this network, strength centrality, closeness, betweenness, expected influence, and bridge strength were computed for each node, and node predictability (R^2) was assessed to characterize the embedded positions and pathways of parenting stress and family adjustment within the children's daily-life functioning difficulties network.

Statistical software

All statistical analyses were performed in R (version 4.5.2). Network estimation and visualization primarily used the *qgraph* (version 1.9.8), *bootnet* (version 1.6), and *networktools* (version 1.5.2) packages; missing-value imputation used the mice (version 3.17.0) package; predictability analysis used the *mgm* (version 1.2-4) package; descriptive statistics and correlation analysis used the psych (version 2.4.6) package. Network estimation following multiple imputation was implemented via a custom R script using Rubin's rules for pooling. Network visualizations were generated using the default Fruchterman–Reingold layout algorithm in *qgraph*.

Use of large language models: During the preparation of this manuscript, KIMI2.6 was used to assist with English language polishing, formatting, and structural organization. All authors reviewed, critically revised, and approved the final manuscript, and take full responsibility for its accuracy and integrity.

Results

Common method bias examination

Harman's single-factor test was used to assess potential common method bias. Unrotated exploratory factor analysis yielded six factors with eigenvalues greater than 1; the first common factor accounted for 36.87% of the total variance, which is below the 40% critical threshold [33], indicating that common method bias was unlikely to be a serious concern in this study.

Descriptive statistics and correlation analysis

This study retrospectively enrolled 1,245 participants. Following the exclusion of participants with excessive missing data or invalid responses, 1,188 participants were included in the final analysis. The demographic and clinical characteristics of the sample are summarized in Table 1. Continuous variables, including child age and parental years of education years, are expressed as mean ± standard deviation (SD), whereas categorical variables are reported as frequencies and percentages. The final sample comprised 839 boys (70.6%) and 349 girls (29.4%). In terms of clinical status, 1,000 participants (84.2%)

were evaluated at their first-visit, whereas 188 (15.8%) were follow-up participants. Most participants were medication-naive (n = 1,086, 91.4%), while 102 (8.6%) participants received medication treatment. In addition, 742 (62.5%) participants had siblings, whereas 446 only children (37.5%).

Table 1
Sociodemographic and clinical characteristics of participants (N = 1188).

Variable	Value
Sex	
Boy	839 (70.6%)
Girl	349 (29.4%)
Diagnosis	
First visit	1000 (84.2%)
Follow-up	188 (15.8%)
Medication	
Medication-naive	1086 (91.4%)
Previously medicated	102 (8.6%)
Only child	
No	742 (62.5%)
Yes	446 (37.5%)
Education years (Mother)	13.88 ± 3.34
Education years (Father)	14 ± 3.77

Data are presented as M ± SD for continuous variables and as n (%) for categorical variables.

Descriptive statistics and distributional characteristics for the 18 QCD items are presented in Table 2. Mean item scores ranged from 1.255 to 2.524. Among all items, "Does homework without difficulties" (QCD11) showed the lowest score (1.255 ± 0.861), suggesting that homework-related functioning represented the area of greatest difficulty among children with ADHD. By contrast, whereas "Parents comfortable in shared activities" (QCD14) yielded the highest mean score (2.524 ± 0.742), indicating relatively better preserved functioning in parent-child shared activities. Examination of item distributions demonstrated that most items exhibited negative skewness, reflecting the high frequency of reported functional difficulties within this ADHD sample. Kurtosis analyses indicated that most items were negatively skewed, consistent with the high prevalence of difficulty-related behaviors in this clinical ADHD sample.

Table 2
Descriptive statistics and distributional properties of the 18 QCD items (N = 1188).

Variable	Item abbreviation	Mean	SD	Skewness	Kurtosis	Presence (%)
QCD1	Gets out of bed promptly	1.927	0.954	-0.511	-0.711	67.424
QCD2	Grooms promptly (washing, dressing)	1.487	0.958	0.007	-0.946	83.754
QCD3	Age-appropriate behavior at breakfast	2.239	0.834	-0.732	-0.481	52.946
QCD4	Trouble-free morning before school	2.145	0.948	-0.795	-0.455	53.956
QCD5	Likes going to school	2.116	0.858	-0.680	-0.298	61.532
QCD6	Behaves in class like peers	1.976	0.860	-0.352	-0.766	68.434
QCD7	Has accepting friends at school	2.110	0.809	-0.451	-0.697	63.384
QCD8	Discusses school events with parents	2.077	0.896	-0.559	-0.688	60.606
QCD9	Has same-age friends	2.163	0.784	-0.483	-0.685	61.279
QCD10	Joins extracurricular activities confidently	2.403	0.781	-1.030	0.021	42.761
QCD11	Does homework without difficulties	1.255	0.861	0.222	-0.620	92.172
QCD12	Enjoys family time without quarrels	2.311	0.827	-1.040	0.355	49.327
QCD13	Calm during dinner conversations	2.220	0.786	-0.740	-0.058	58.418
QCD14	Parents comfortable in shared activities	2.524	0.742	-1.457	1.326	34.428
QCD15	Night activities with friends (adolescents)	1.606	1.351	-0.153	-1.781	57.407
QCD16	Follows night instructions (younger)	2.450	0.783	-1.439	1.567	40.404
QCD17	Falls asleep without difficulties	2.392	0.787	-1.176	0.729	44.697

Note. QCD = Questionnaire: Children with Difficulties. SD = standard deviation; Presence = percentage of participants endorsing the symptom (score ≥ 1). Skewness and kurtosis are unstandardized values. All items were rated on a 4-point scale from 0 to 3.

Variable	Item abbreviation	Mean	SD	Skewness	Kurtosis	Presence (%)
QCD18	Sleeps without waking at night	2.350	0.920	-1.285	0.590	41.077

Note. QCD = Questionnaire: Children with Difficulties. SD = standard deviation; Presence = percentage of participants endorsing the symptom (score ≥ 1). Skewness and kurtosis are unstandardized values. All items were rated on a 4-point scale from 0 to 3.

The correlation matrix among QCD, PSI, and PAFAS subscales is presented in Fig. 1. The five QCD time-of-day dimensions were moderately positively intercorrelated (r = 0.259–0.589), with the strongest association observed between the School and After School dimensions (r = 0.589), suggesting a tendency for functional difficulties to co-occur across time periods. All QCD dimensions were moderately to strongly negatively correlated with the three PSI dimensions (r = − 0.797 to − 0.344); the strongest negative association observed between the QCD Night dimension and the PSI Parent Domain (PSI-PD) (r = − 0.774. Notably, strong negative correlations were also found between the QCD School and After School dimensions and the PSI Child Domain (PSI-CD) (r = − 0.797). Similarly, QCD dimensions were moderately to strongly negatively correlated with the three PAFAS dimensions (r = − 0.734 to − 0.361), with the strongest negative correlation observed between the QCD Evening dimension and PAFAS Parental Teamwork (PAFAS-PN) (r = − 0.734). In contrast, PSI dimensions were moderately to strongly positively intercorrelated with PAFAS dimensions (r = 0.522–0.862), with the strongest positive association observed between the PSI Life Stress Domain (PSI-LSD) and PAFAS Family Relationships (PAFAS-FR) (r = 0.862). Overall, these correlation patterns provided preliminary support for the subsequent extended network analysis.

QCD symptom network analysis

The EBICglasso-estimated network structure of the 18 QCD items is shown in Fig. 2. The network showed relatively dense overall connectivity, with clear clustering of items within each time-of-day dimension alongside, cross-dimensional connections. This pattern suggests both within-time clustering and cross-time interaction in daily-life difficulties among children with ADHD..

The strongest edge in the network was observed between the After School dimension item "Has same-age friends" (QCD9) and the School dimension item "Has accepting friends at school" (QCD7) (w = 0.494), indicating the strongest conditional dependency between peer acceptance in school and peer interaction after school. This finding suggests a high degree of continuity in social functioning difficulties across contexts in children with ADHD. Other relatively strong edges included the Morning items "Gets out of bed promptly" (QCD1) and "Grooms promptly (washing, dressing)" (QCD2) (w = 0.334), suggesting that morning arousal and self-care behaviors may share a common executive-function bias. In the Night dimension, "Follows night instructions" (QCD16) and "Falls asleep without difficulties" (QCD17) (w = 0.327) were strongly connected, reflecting a close association between pre-sleep behavioral regulation and sleep-onset processes. In addition, the After School items, "Has same-age friends" (QCD9) and

"Joins extracurricular activities confidently" (QCD10) (w = 0.299) showed a notable connection, indicating an association between peer relationships and participation in structured activities. Finally, within the Evening dimension, "Calm during dinner conversations" (QCD13) and "Parents comfortable in shared activities" (QCD14) (w = 0.245) were linked, reflecting coherence in family interaction quality during evening routines.

A small number of negative edges were present in the network, all with small absolute values: the School dimension item "Likes going to school" (QCD5) and the Night dimension item "Night activities with friends (adolescents)" (QCD15) (w = − 0.061); the Evening dimension item "Does homework without difficulties" (QCD11) and the Night dimension item "Night activities with friends" (QCD15) (w = − 0.056); the After School dimension item "Discusses school events with parents" (QCD8) and the Night dimension item "Sleeps without waking at night" (QCD18) (w = − 0.022); and the Morning dimension item "Gets out of bed promptly" (QCD1) and the School dimension item "Has accepting friends at school" (QCD7) (w = − 0.008). These negative edges suggest the possible presence of weak resource competition or context-specific regulatory effects across certain functional domains.

Node predictability analysis showed that the overall average predictability of the network was 33.5%, indicating that approximately one-third of node variance could be explained by directly connected neighboring nodes within the network. Among them, "Has same-age friends" (QCD9, $R^2 = 0.541$) and "Has accepting friends at school" (QCD7, $R^2 = 0.516$) showed the highest predictability, suggesting that more than half of the variance in these two social-functioning nodes could be explained by other nodes in the network, indicating that they are highly embedded symptoms within the network. "Follows night instructions" (QCD16, $R^2 = 0.374$) and "Age-appropriate behavior at breakfast" (QCD3, $R^2 = 0.379$) also showed relatively high predictability. By contrast, "Sleeps without waking at night" (QCD18, $R^2 = 0.118$) and "Grooms promptly (washing, dressing)" (QCD2, $R^2 = 0.171$) showed the lowest predictability, suggesting that variance in these nodes is attributable to factors external to the network (e.g., biological rhythms, neurodevelopmental maturity, or family- and environment-specific factors).

Bootstrap confidence-interval analysis showed that the aforementioned negative edges and the vast majority of positive edges had 95% confidence intervals that did not include zero (Fig. 3), indicating satisfactory stability and statistical reliability of network edge-weight estimates.

Network centrality indices

Standardized centrality indices for the 18 items are shown in Fig. 4. For strength centrality, "Follows night instructions" (QCD16) ranked highest, followed by "Trouble-free morning before school" (QCD4, z = 0.915) and "Has same-age friends" (QCD9, z = 0.876), indicating that these nodes had the highest total connection strength with other nodes in the network and are the most important central nodes with the strongest direct influence on the overall network. For closeness centrality, "Trouble-free morning before school" (QCD4, z = 0.923) and "Follows night instructions" (QCD16, z = 0.936) ranked highest, suggesting that these two nodes have the shortest average shortest-path distance to other nodes in the network

and the highest information-transmission efficiency, occupying central topological positions in the network.

The distribution of betweenness centrality showed marked non-equilibrium characteristics. "Age-appropriate behavior at breakfast" (QCD3, z = 2.964) exhibited exceptionally high betweenness, far exceeding all other nodes, indicating that this node serves as the most important "bridge" in the network, controlling a large proportion of cross-node information-transmission paths. "Behaves in class like peers" (QCD6, z = 1.071) and "Trouble-free morning before school" (QCD4, z = 0.716) also demonstrated relatively high betweenness. The high betweenness of QCD3 may reflect that breakfast behavior, as a critical transition point in daily functioning from nighttime rest to daytime activity, connects the two major functional systems of night rest and daytime activity.

Bridge node analysis

Bridge-strength results are shown in Fig. 5. "Trouble-free morning before school" (QCD4, bridge strength = 0.678), "Likes going to school" (QCD5, bridge strength = 0.673), and "Has accepting friends at school" (QCD7, bridge strength = 0.669) showed the highest bridge strength, indicating that these nodes play the most important bridging roles in connecting different time-of-day difficulty dimensions and serve as key pathways for cross-time-period symptom spread and cascade activation. "Does homework without difficulties" (QCD11, bridge strength = 0.608), "Has same-age friends" (QCD9, bridge strength = 0.582), and "Discusses school events with parents" (QCD8, bridge strength = 0.568) also showed relatively high bridge strength, suggesting that academic behavior, social behavior, and parent–child communication likewise play important roles in linking different time-period functional domains. By contrast, "Grooms promptly (washing, dressing)" (QCD2, bridge strength = 0.000) and "Sleeps without waking at night" (QCD18, bridge strength = 0.161) showed the lowest bridge strength, being largely confined to their own dimensions with limited cross-time-period influence.

Network stability

Bootstrap-based stability analysis showed that the CS-Coefficients for the three centrality indices in the QCD network were: strength centrality, 0.789; betweenness centrality, 0.545; and closeness centrality, 0.667. According to the criteria proposed by Epskamp et al. (2018) [10], the CS-Coefficient for strength centrality far exceeded the good-stability threshold of 0.50, and both closeness centrality and betweenness centrality also exceeded this threshold. Overall, these results indicate that network centrality indices demonstrate satisfactory stability and estimation accuracy.

Extended network: associations among difficulties, parenting stress, and family adjustment

To explore the association patterns between ADHD children's daily-life difficulties and parenting stress and family functioning, the extended network incorporated five QCD time-of-day dimensions (Morning, School, After School, Evening, Night), three PSI-SF dimensions (Parent Domain [PD], Child Domain [CD],

Life Stress Domain [LSD]), and three PAFAS dimensions (Parental Adjustment [PC], Family Relationships [FR], Parental Teamwork [PN]), for a total of 11 nodes. The network structure is shown in Fig. 6.

Edge-weight analysis revealed extensive and specific connections between QCD dimensions and PSI and PAFAS dimensions. The PSI Parent Domain (PSI-PD) showed the strongest negative correlation with the QCD Night dimension (w = − 0.763), indicating the most direct and strongest conditional dependency between parental psychological stress and children's nighttime sleep difficulties. The PSI Child Domain (PSI-CD) showed strong negative correlations with the QCD School dimension (w = − 0.600) and the After School dimension (w = − 0.643), suggesting that parent-perceived child problem-behavior stress is concentrated primarily in the school-adaptation and after-school homework periods. PAFAS Parental Teamwork (PAFAS-PN) showed a strong negative correlation with the QCD Evening dimension (w = − 0.427), indicating that the degree of parenting cooperation between parents is closely related to children's evening functioning; PAFAS Family Relationships (PAFAS-FR) showed a moderate negative correlation with the QCD Morning dimension (w = − 0.250), suggesting that family relationship quality has a domain-specific influence on morning functioning. In addition, the PSI Life Stress Domain (PSI-LSD) showed a strong positive correlation with PAFAS Family Relationships (PAFAS-FR) (w = 0.370), indicating that life stress may indirectly affect children's behavior by impairing family relationships, supporting the mediating role of family functioning in stress transmission.

For node predictability, PSI-CD (R^2 = 0.901) and PSI-PD (R^2 = 0.888) showed the highest predictability, indicating that the vast majority of variance in these two core dimensions of parenting stress could be explained by other nodes in the network (including children's difficulties and other family factors), making them highly embedded nodes in the extended network. Predictability for the QCD dimensions ranged from 0.707 to 0.772; the Morning dimension (0.772) and Night dimension (0.765) were relatively high, suggesting that difficulty behaviors during these two time periods are more strongly driven by intra-network factors, whereas the School dimension (0.707) was relatively low, possibly being more influenced by extra-network factors (e.g., teacher expectations and classroom environment).

Centrality analysis results are presented in Fig. 7. In terms of strength centrality, PSI-PD (z = 1.071) and PSI-LSD (z = 1.028) showed the highest values, indicating that these nodes had the strongest connections within the extended network. This finding suggests that parenting stress occupies a central position in the network linking children's difficulties and family functioning. Regarding closeness centrality, PAFAS-PN (z = 1.440) and QCD Evening (z = 1.102) ranked highest, indicating that these nodes had the shortest average distance to other nodes in the network and the greatest accessibility to network-wide information. Notably, QCD Evening (z = 1.933) and PAFAS-PN (z = 1.933) demonstrated the highest betweenness centrality, with values substantially exceeding those of the remaining nodes. This result suggests that evening child-behavior difficulties and parental cooperation function as key bridging nodes within the child-behavior–parenting-stress–family-functioning system, facilitating connections across different domains of the network.

Overall, the extended network analysis identified parenting stress (particularly PSI-PD and PSI-CD), evening child-behavior difficulties, and parental cooperation as the most central nodes in the network. From a family-systems perspective, these findings suggest that interventions targeting these factors may yield the greatest overall improvement across the broader network.

Discussion

This study employed network analysis methods to systematically explore the internal network structure of daily-life difficulties in children with ADHD, identify central and bridge symptoms within the network, and examine the relationships among parenting stress, family adjustment, and the children's difficulty network. The major findings were as follows: (1) the daily-life difficulty network of children with ADHD showed clear time-period clustering characteristics alongside cross-time-period functional connections; (2) "Follows night instructions," "Trouble-free morning before school," and "Has same-age friends" were central symptoms in the network, whereas "Trouble-free morning before school," "Likes going to school," and "Has accepting friends at school" were the most important bridge symptoms; (3) parenting stress and poor family adjustment showed specific associations with children's difficulties across multiple time periods, while parenting-stress and family-adjustment factors occupied core positions and served as bridging roles in the extended network.

Network structural characteristics of daily-life difficulties in children with ADHD

The QCD difficulty network constructed in this study displayed a clear time-period clustering structure, with items within each dimension tending to cluster together, which is consistent with the theoretical structure of the QCD scale [23]. However, significant cross-dimensional connections were also present in the network, indicating that difficulties across different time periods are not isolated but form a complex dynamic network system through symptom interactions. This finding supports the core tenet of network theory that mental-disorder symptoms mutually activate and maintain one another [11, 13], and further extends this theoretical perspective from traditional ADHD core-symptom networks to the domain of daily-life functioning.

In terms of network centrality, "Follows night instructions" (QCD16) showed the highest strength centrality, suggesting that this symptom had the strongest overall connections with other symptoms in the network and represented the most influential core node. Sleep problems are highly prevalent among children with ADHD and include sleep-onset difficulties, nighttime awakenings, and poor sleep quality, with reported prevalence rates ranging from 25%–55% [39, 40]. Our findings further suggest that sleep-related difficulties may function as a "hub" in the daily-life difficulty network of children with ADHD. Sleep difficulties may not only directly impair children's daytime attention and emotion regulation, but also contribute to the activation of difficulty behaviors across other time periods through cascading effects [6, 39]. In recent years, increasing attention has been paid to conceptualizing ADHD as a "24-hour disorder," in which impairments extend across both daytime and nighttime, thereby necessitating

integrated treatment approaches that address daytime symptoms alongside sleep-related challenges [39]. The central position of QCD16 in the present study provides network-level empirical support for this perspective.

"Trouble-free morning before school" (QCD4) also demonstrated high strength centrality and closeness, and its predictability was relatively high ($R^2 = 0.376$), indicating that morning-period difficulties are substantially influenced by other symptoms in the network. The morning period involves a series of executive-function-dependent tasks such as waking up, dressing, and preparing for school, and executive-function deficits are recognized as a core cognitive characteristic of ADHD [41]. From a network perspective, morning difficulties may be both a downstream consequence of nighttime sleep problems and an upstream contributor to school-period functional impairment, thereby occupying a key position in network topology.

"Has same-age friends" (QCD9) and "Has accepting friends at school" (QCD7) showed the highest predictability ($R^2 = 0.541$ and 0.516, respectively), indicating that more than half of the variance in these two social-functioning nodes could be explained by other nodes in the network. This finding suggests that social-functioning difficulties in children with ADHD are not isolated ability deficits but are closely interconnected with the overall daily-life difficulty network. Improving other nodes in the network (e.g., sleep, morning preparation) may indirectly enhance children's peer-relationship quality through cascade effects. Previous research has also shown that social difficulties in children with ADHD are closely related to multi-time-period functional impairments and seriously affect long-term quality of life [4].

Notably, "Age-appropriate behavior at breakfast" (QCD3) showed exceptionally high betweenness ($z = 2.964$), far exceeding all other nodes. Although QCD3 was not the most prominent in terms of strength centrality, its frequent occurrence on the shortest paths within the network indicates that it functions as a latent bridge connecting the Morning dimension to other time-period dimensions, particularly the School and Night dimensions). Breakfast behavior, as a critical transition point between the home and school environments, may involve multiple cognitive and social processes, including executive functioning, emotion regulation, and family interaction, all of which share common neurocognitive foundations with both daytime and nighttime functioning. This finding extends beyond traditional variable-centered paradigms based on correlation or regression analyses and highlights the unique utility of network analysis in identifying non-intuitive yet influential nodes within complex systems.

Clinical significance of bridge symptoms

Bridge-node analysis revealed key symptoms that connect different time-period dimensions within the network. "Trouble-free morning before school" (QCD4) showed the highest bridge strength while also exhibiting relatively high betweenness, indicating that this node served as the most important bridge connecting the Morning dimension to other time-period dimensions (particularly Evening and Night). Morning preparation involves multiple cognitive processes such as executive functioning, time management, and emotion regulation, which share common neurocognitive resources with evening and nighttime behaviors (e.g., homework completion, and sleep preparation). Therefore, difficulties in

morning preparation may influence functional performance in other time periods through shared cognitive mechanisms, and vice versa.

"Likes going to school" (QCD5) and "Has accepting friends at school" (QCD7) also showed high bridge strength, suggesting that they play important roles in connecting the School dimension with the After School and Evening dimensions. School behavioral performance not only affects classroom learning but may also influence after-school family interaction and evening homework completion through parent–teacher feedback, homework demands, and peer relationships [42]. This finding suggests that school-period social and behavioral interventions may produce cross-time-period spillover effects, improving children's functional performance in other time periods.

From a network-intervention perspective, bridge symptoms are considered ideal intervention targets. According to network theory, intervening on bridge symptoms may break connections between dimensions, preventing symptom spread and cascade activation within the network [14, 16]. For example, improving morning preparation routines and establishing regular morning schedules may not only directly reduce morning difficulties but also indirectly improve evening and nighttime functioning by supporting more stable daily rhythms. Blanken et al. [43] further noted that symptoms with both high centrality and high bridge centrality often have the strongest network-stabilizing effects, and interventions targeting these nodes are expected to produce maximal overall network improvement.

Relationships among parenting stress, family adjustment, and children's difficulties

Extended network analysis revealed complex associations between parenting stress, family adjustment, and children's daily-life difficulties. The strongest negative correlation between the PSI Parent Domain (PSI-PD) and the QCD Night dimension (w = − 0.763) is particularly noteworthy. This finding indicates that parental psychological stress (e.g., depression, anxiety, role restriction) is closely related to children's nighttime difficulties (sleep-onset difficulties, poor sleep quality). This association is likely bidirectional: on the one hand, children's sleep problems may increase parental nighttime monitoring stress, thereby exacerbating parental psychological burden; on the other hand, high parental stress may worsen children's sleep difficulties by affecting family routines and pre-sleep interaction quality [39, 44]. Previous studies have shown that primary caregivers of children with ADHD are at 2.7 times greater risk for clinical-level depression, stress, or anxiety than caregivers of typically developing children [39]; our study further identifies the specific connection between parental stress and children's nighttime difficulties from a network perspective.

The strong negative correlations between the PSI Child Domain (PSI-CD) and the QCD School dimension (w = − 0.600) and After School dimension (w = − 0.643) suggest that parent-perceived child problem-behavior stress is concentrated primarily in the school-adaptation and after-school homework periods. This is consistent with the manifestation characteristics of ADHD core symptoms—namely that inattention and hyperactive/impulsive symptoms are most prominent in school settings, and homework completion difficulty is one of the most commonly reported parental concerns [45, 46]. From the item-

level inference, PSI-CD is most strongly associated with "Has accepting friends at school" (QCD7), "Has same-age friends" (QCD9), and "Joins extracurricular activities confidently" (QCD10), further confirming that school-related functioning is a major source of parenting stress for children with ADHD.

Regarding family adjustment, the negative correlation between PAFAS Family Relationships (PAFAS-FR) and the QCD Morning dimension (w = − 0.250) suggests that family relationship quality directly affects children's morning-period functioning. The morning period is one of the most family-interaction-dense periods of the day, involving parental wake-up, prompting, and assisting the child in completing a series of preparation tasks. Harmonious family relationships may promote positive parent–child interaction, whereas conflictual family atmospheres may exacerbate morning chaos and difficulties. The strong negative correlation between PAFAS Parental Teamwork (PAFAS-PN) and the QCD Evening dimension (w = − 0.427) indicates that parental consistency and cooperation in parenting issues are closely related to children's evening functioning. The evening period involves multiple tasks such as homework supervision, dinner arrangements, and bedtime preparation, requiring coordination between parents; poor parental cooperation may lead to inconsistent parenting strategies, thereby exacerbating children's behavioral problems during the evening period [26].

Centrality analysis in the extended network further revealed the structural positions of parenting stress and family adjustment factors within the network. PSI-PD and PSI-LSD showed the highest strength centrality, indicating that these nodes are the most central within the extended network and suggesting that parenting stress is a key hub connecting children's difficulties and family functioning. More importantly, QCD Evening and PAFAS-PN showed the highest and equal betweenness, far exceeding other nodes, suggesting that these two nodes play equally important and pivotal bridging roles in the child-behavior–parenting-stress–family-functioning tripartite system. This finding supports the family-system-theory perspective that children's symptoms, parenting stress, and family interaction are not independent variables but constitute a mutually nested, feedback-driven family system [46]. Within this system, the evening period appears to be a critical "stress convergence point," where children's evening behavioral difficulties are simultaneously influenced by parental cooperation quality and, in turn, affect parenting stress levels, forming a potential vicious cycle.

Clinical implications

The findings of this study have the following implications for clinical assessment and intervention for children with ADHD:

First, regarding assessment, comprehensive evaluation of functional difficulties across different daily-life time periods in children with ADHD should be emphasized, rather than focusing solely on core symptoms. The time-period-specific difficulty patterns revealed by network analysis suggest that instruments such as the QCD can serve as important supplements to core-symptom assessment, helping clinicians identify specific functional difficulty nodes in children's daily lives, particularly central symptoms within the network such as sleep-related difficulties, morning preparation, and peer interaction.

Second, regarding intervention target selection, priority should be given to central and bridge symptoms in the network. "Follows night instructions" and "Trouble-free morning before school," as symptoms with both high centrality and high bridge centrality, are ideal intervention targets. Interventions targeting these symptoms may improve overall network functional status through cascade effects [16]. Meanwhile, "Likes going to school" and "Has accepting friends at school," as bridge symptoms connecting the School and After School dimensions, suggest that school-based social-functioning interventions may produce cross-time-period spillover effects.

Third, regarding intervention strategies, comprehensive family-system-oriented interventions should be adopted. Extended network analysis showed that parenting stress and poor family adjustment are closely related to children's difficulties, with time-period-specific association patterns. Therefore, interventions should not focus exclusively on the child but should also include parental psychological support, family-functioning improvement, and parental-cooperation promotion at the family level [26, 47]. Specifically, interventions for nighttime difficulties should simultaneously address parental stress management and sleep-hygiene education; interventions for school/after-school difficulties should help parents establish effective behavior-management strategies and home–school communication mechanisms; and interventions for morning and evening difficulties should improve family interaction patterns and parental cooperation.

Comparison with previous research

Our findings share similarities with yet offer unique contributions beyond previous ADHD network-analysis research. Regarding ADHD core-symptom networks, Liu et al. [18] found that "Easily distracted" and "Fidgets" were key bridge symptoms connecting the inattention and hyperactivity/impulsivity symptom clusters; the bridge symptoms identified in our study ("Trouble-free morning before school" and "Likes going to school") are functionally similar in that they both involve cross-domain or cross-time-period connecting functions. Silk et al. [17] found that hyperactive/impulsive symptoms clustered more tightly in the network, whereas in our study the clustering degrees of the time-period dimensions were relatively balanced, possibly reflecting structural differences between the QCD as a functional assessment tool and DSM symptom-based assessments: QCD items are organized by temporal ecology rather than symptom categories, thus presenting more balanced multi-dimensional clustering.

Compared with previous studies examining the relationship between parenting stress and children's symptoms, the unique contribution of this study lies in adopting a network-analysis perspective to reveal the network associations among parenting stress, family adjustment, and children's difficulties. Previous studies have mostly used correlation or regression analysis to examine linear relationships among variables [44], whereas our extended network revealed more complex, non-linear association patterns, including specific associations between different family factors and different time-period difficulties, as well as the structural positions of family factors within the network. This finding supports the family-system-theory perspective on the interaction between family factors and children's behavior [46] and provides empirical evidence for more precise, system-level interventions.

Limitations and future directions

This study has the following limitations. First, the retrospective cross-sectional design cannot establish causal relationships; edge weights in network analysis reflect partial correlation relationships rather than causal effects. Future studies may adopt longitudinal designs or experience sampling methods (ESM) to examine dynamic changes in symptom networks. Second, the sample was drawn from a single medical center, which may involve selection bias; future validation in community samples is needed. Third, all measurements relied on parent reports, which may involve common method bias; future studies should incorporate teacher reports, child self-reports, and objective observations [24]. Fourth, EBICglasso estimation is sensitive to sample size, and regularization methods may shrink weak connections to zero [26]. Fifth, child age, sex, ADHD subtype, and other demographic variables were not included, and these factors may affect network structure [48]. Sixth, the QCD General Behavior dimension was not included in the analysis; future studies may include it for a more comprehensive representation of the functional difficulty network. Seventh, child comorbidities, medication status, family socioeconomic status, and other variables were not included; future studies should construct more comprehensive network models.

Conclusions

This study used network analysis methods to systematically explore the internal structural characteristics of daily-life difficulties in children with ADHD and their relationship with parenting stress and family adjustment. The study found that the difficulty network of children with ADHD has clear time-period clustering characteristics; "Follows night instructions," "Trouble-free morning before school," and "Has same-age friends" are central symptoms in the network, while "Trouble-free morning before school," "Likes going to school," and "Has accepting friends at school" are the most important bridge symptoms. Parenting stress and poor family adjustment showed specific associations with children's difficulties in different time periods, with particularly prominent connections between Parent Domain stress and nighttime difficulties, Child Domain stress and school/after-school difficulties, family relationships and morning difficulties, and parental cooperation and evening difficulties. These findings provide important evidence for precise assessment and comprehensive intervention for children with ADHD, suggesting that clinical practice should pay attention to key nodes in the symptom network and adopt family-system-oriented, time-period-specific intervention strategies to maximize cascade effects and cross-time-period spillover effects.

Abbreviations

ADHD: Attention-deficit/hyperactivity disorder

ABCD: Adolescent Brain and Cognitive Development

CMB: Common method bias

CS-Coefficient: Correlation stability coefficient

DSM-5: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition

EBIC: Extended Bayesian information criterion

ESM: Experience sampling method

GGM: Gaussian graphical model

GLASSO: Graphical least absolute shrinkage and selection operator

LSD: Life Stress Domain

PAFAS: Parenting and Family Adjustment Scales

PAFAS-FR: Parenting and Family Adjustment Scales – Family Relationships

PAFAS-PN: Parenting and Family Adjustment Scales – Parental Teamwork

PAFAS-PC: Parenting and Family Adjustment Scales – Parental Adjustment

PCA: Principal component analysis

PD: Parent Domain

PMM: Predictive mean matching

PSI: Parenting Stress Index

PSI-CD: Parenting Stress Index – Child Domain

PSI-LSD: Parenting Stress Index – Life Stress Domain

PSI-PD: Parenting Stress Index – Parent Domain

PSI-4 SF: Parenting Stress Index-4 Short Form

QCD: Questionnaire: Children with Difficulties

R^2: Coefficient of determination

SD: Standard deviation

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of The Affiliated Suzhou Hospital of Nanjing Medical University (approval number: 17-K-2025-170-K01). All parents or legal guardians of participating children provided signed informed consent.

Consent for publication

Not applicable. This manuscript does not contain any individual person's data, images, or videos that would require consent for publication.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceptualization and study design: RW and YK conceived and designed the study.

Data acquisition: RW, DS, and HJ collected the data and performed quality control.

Statistical analysis and network modeling: RW and YYC performed the statistical analysis, network estimation, bootstrap stability testing, and visualization.

Drafting of the manuscript: RW wrote the first draft of the manuscript.

Critical revision of the manuscript: KY critically revised the manuscript for important intellectual content; HZ, LX, and TYL contributed to literature verification and content review.

Administrative and supervisory support: KY supervised the study and served as the corresponding author.

Final approval: All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Figures

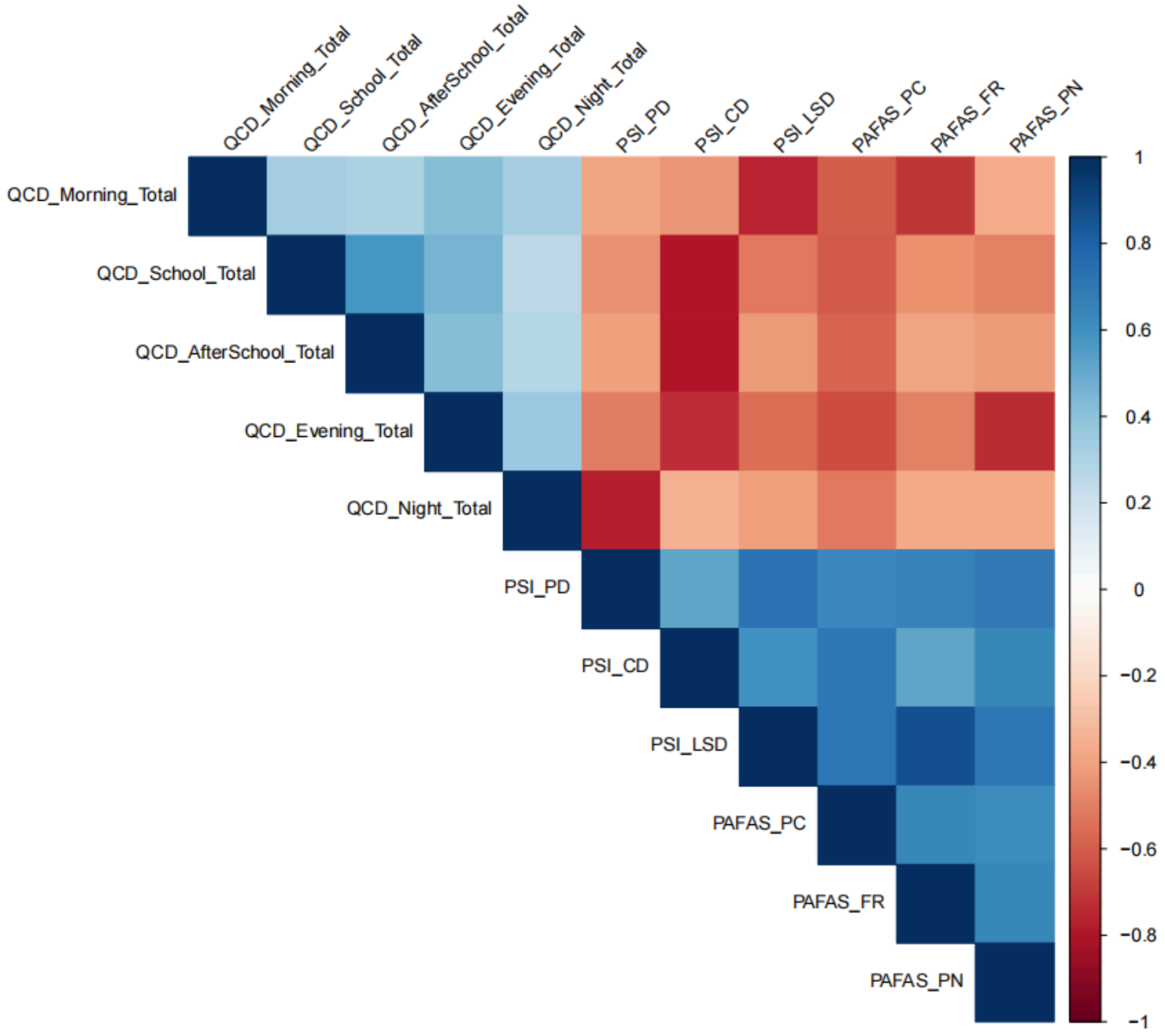


Figure 1

Correlation matrix among QCD, PSI, and PAFAS subscales. Color intensity reflects the magnitude of Pearson correlation coefficients (blue, positive; red, negative). Abbreviations: QCD, Questionnaire: Children with Difficulties; PSI, Parenting Stress Index-4 Short Form; PAFAS, Parenting and Family Adjustment Scales; PD, Parent Domain; CD, Child Domain; LSD, Life Stress Domain; PC, Parental Adjustment; FR, Family Relationships; PN, Parental Teamwork.

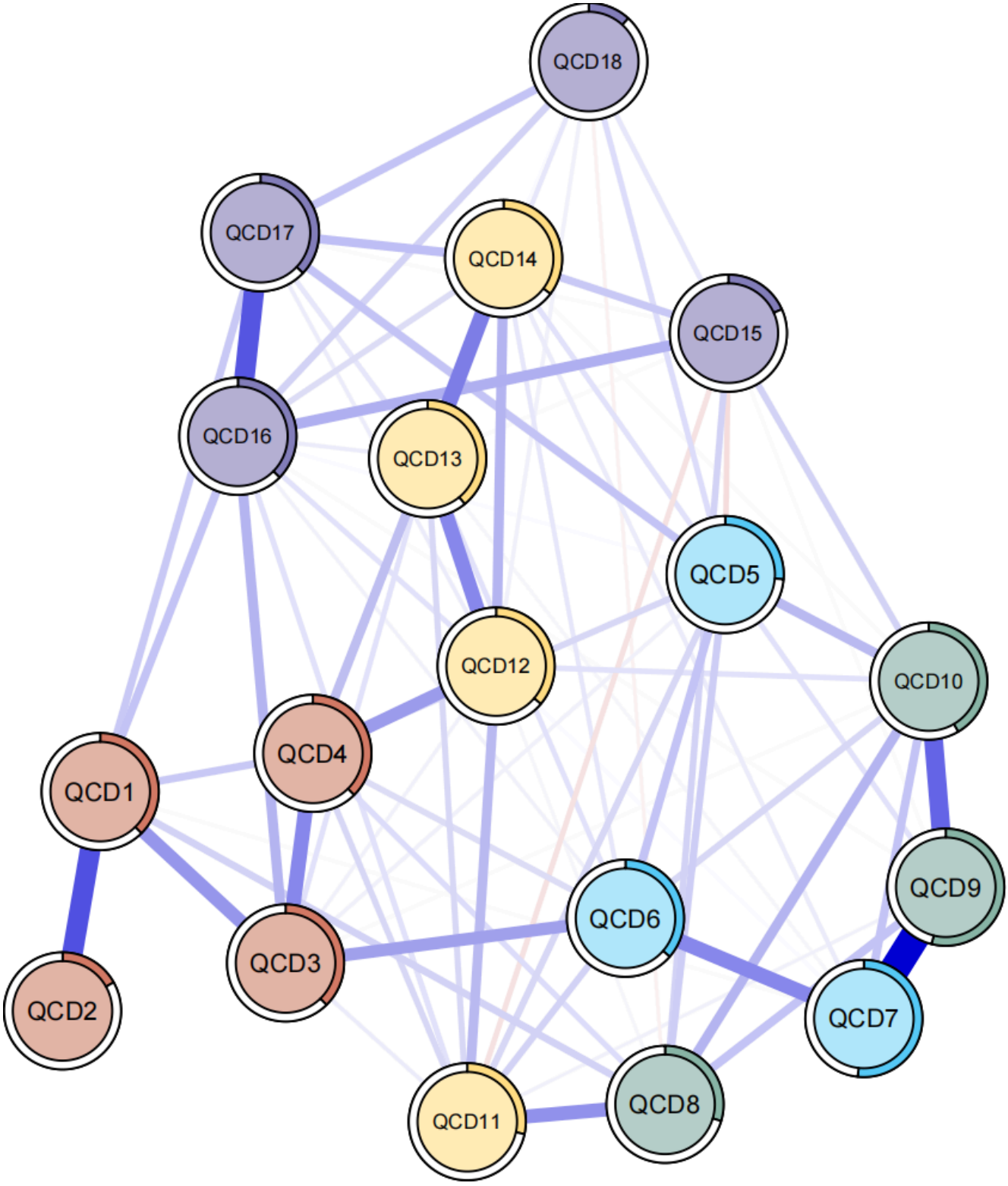


Figure 2

EBICglasso network structure of the 18 QCD items. Nodes represent individual items, color-coded by time-of-day dimension (Morning, green; School, yellow; After School, orange; Evening, purple; Night, blue). Blue edges indicate positive partial correlations, whereas red edges indicate negative partial correlations; edge thickness and transparency reflect the magnitude of the absolute edge weights.

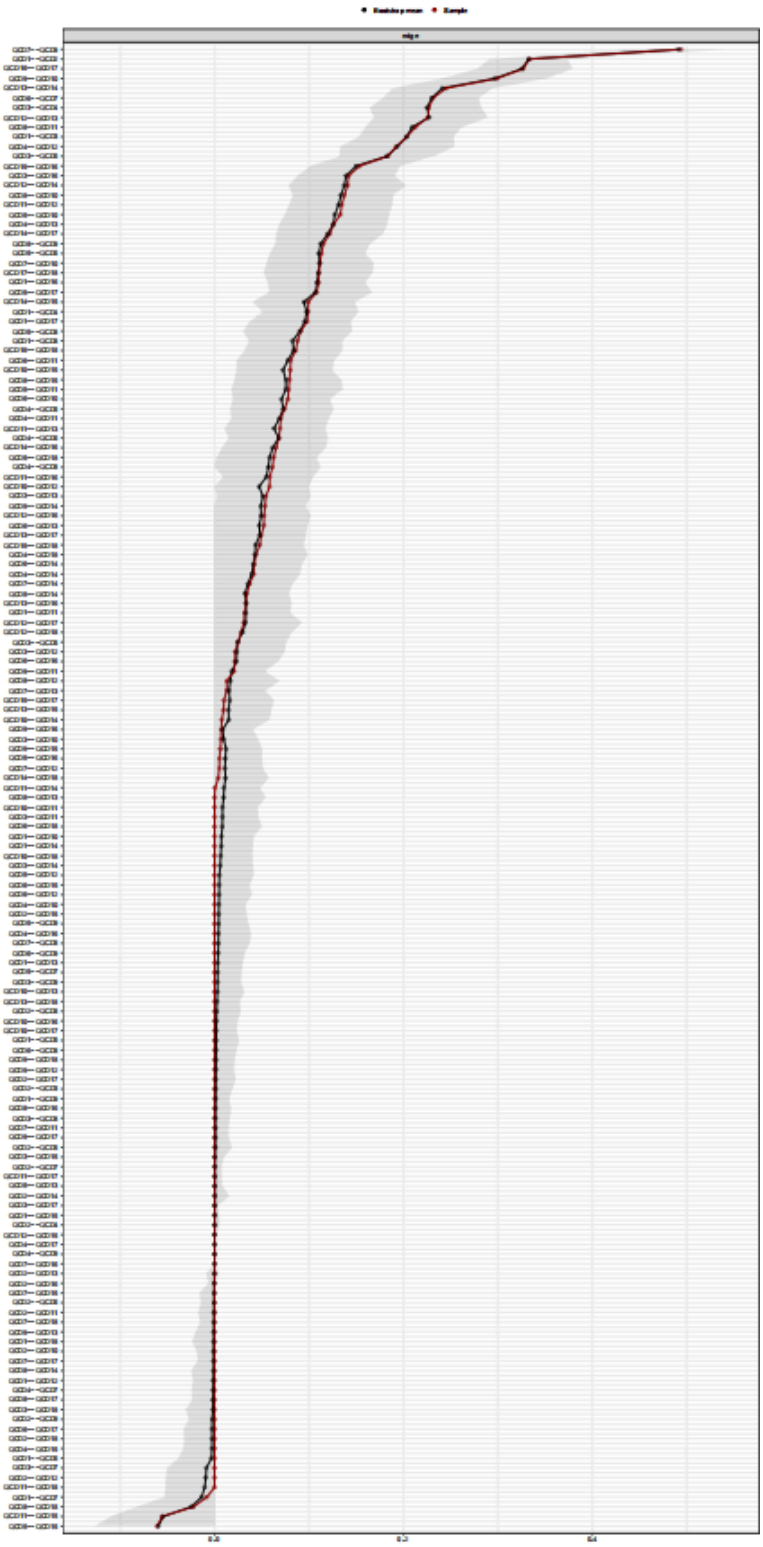


Figure 3

Bootstrapped 95% confidence intervals for edge weights in the QCD network. Confidence intervals were derived from 500 non-parametric bootstrap resamples. Intervals not crossing zero (dashed horizontal line) indicate statistically significant edges. Edges are ordered by absolute weight magnitude.

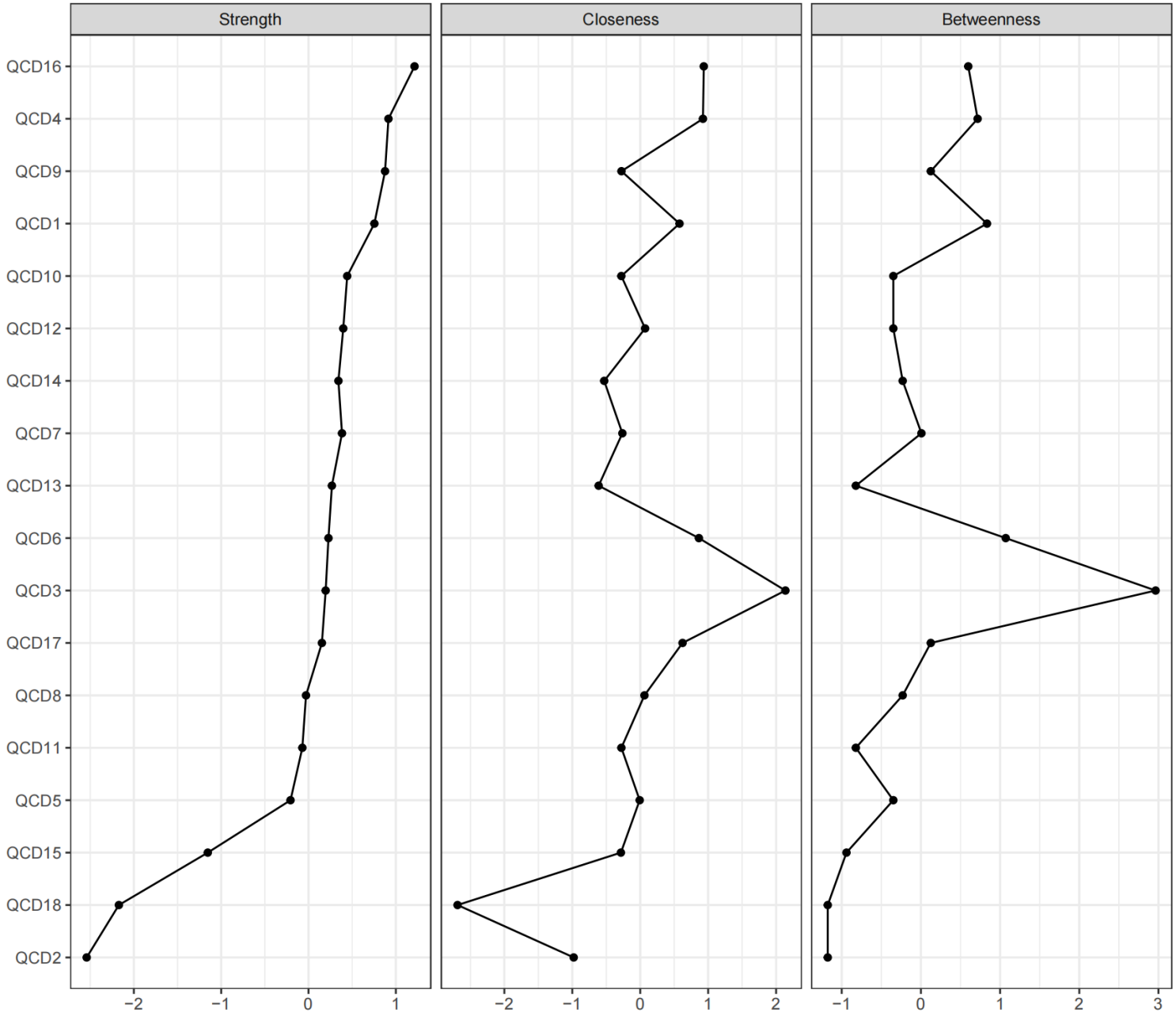


Figure 4

Standardized centrality indices (z-scores) for the 18 QCD items. Panels from left to right represent strength centrality, closeness centrality, betweenness centrality, and expected influence. Higher z-scores indicate greater centrality. Abbreviations: QCD, Questionnaire for Children with Difficulties.

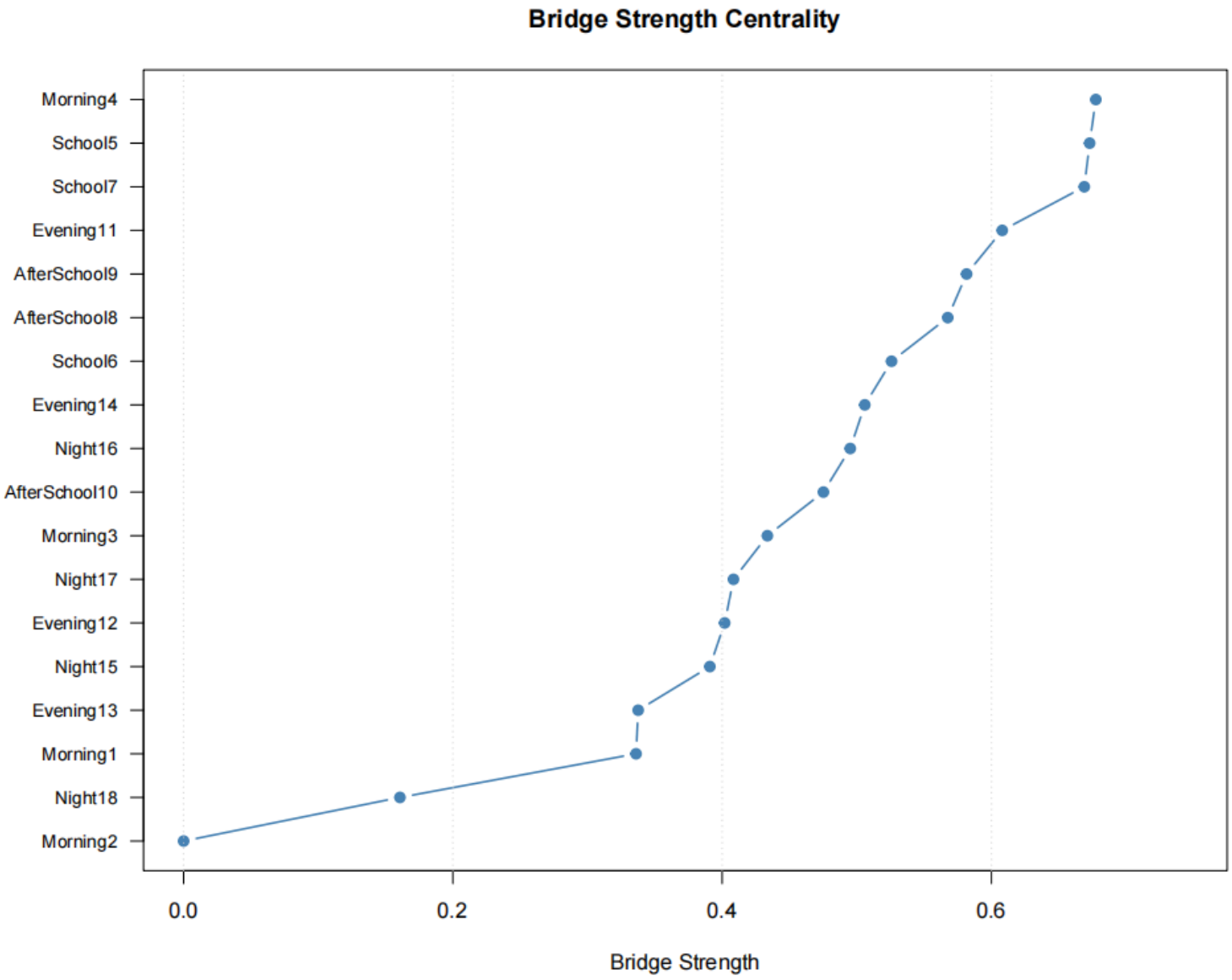


Figure 5

Bridge strength of the 18 QCD items in the network of daily life difficulties among children with ADHD. Bridge strength represents the sum of absolute edge weights connecting a node to nodes in other communities (time-of-day dimensions), reflecting a symptom's role in linking difficulties across different functional periods.

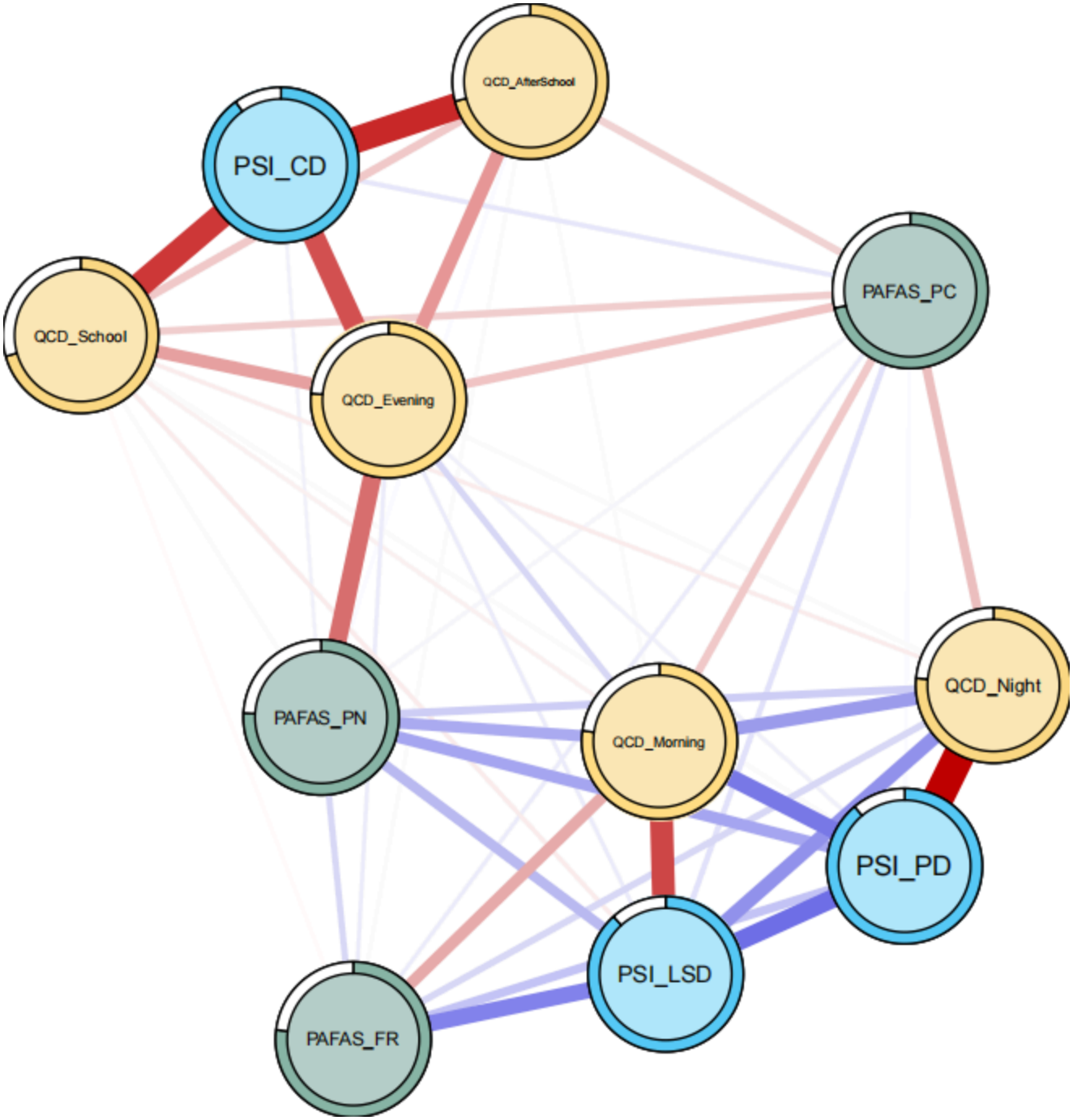


Figure 6

Extended EBICglasso network of daily life difficulties, parenting stress, and family adjustment among children with ADHD. Nodes represent five QCD time-of-day dimensions (Morning, School, After School, Evening, Night), three PSI-SF dimensions (Parent Domain [PD], Child Domain [CD], Life Stress Domain [LSD]), and three PAFAS dimensions (Parental Adjustment [PC], Family Relationships [FR], Parental Teamwork [PN]). Blue edges denote positive partial correlations, red edges denote negative partial correlations; edge thickness and transparency reflect absolute edge weights. QCD, Questionnaire: Children with Difficulties; PSI-SF, Parenting Stress Index-4 Short Form; PAFAS, Parenting and Family Adjustment Scales; PD, Parent Domain; CD, Child Domain; LSD, Life Stress Domain; PC, Parental Adjustment; FR, Family Relationships; PN, Parental Teamwork

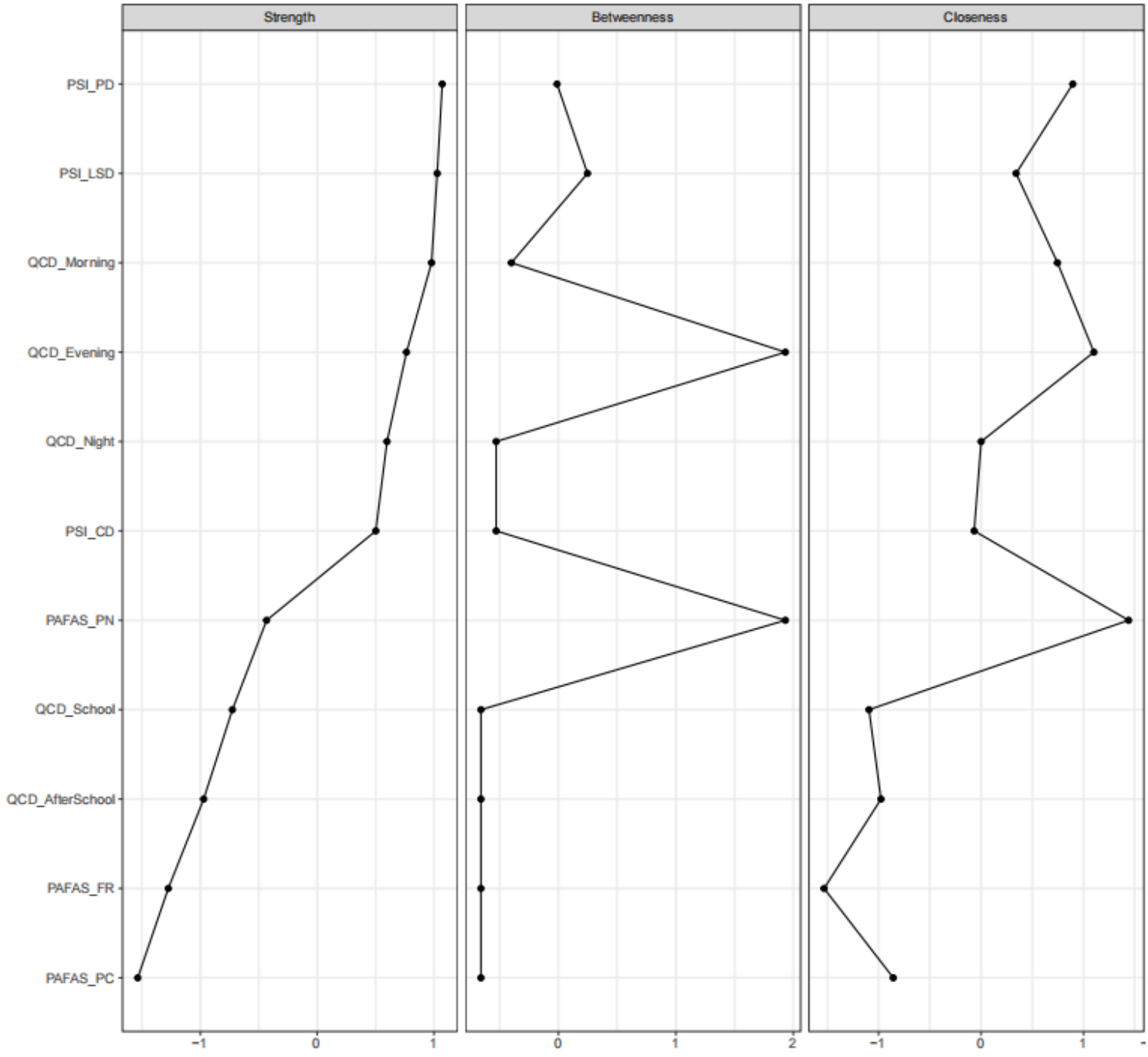


Figure 7

Standardized centrality indices (z-scores) for the 11 nodes in the extended network.